Development of Payload and Platform for Gamma-ray Energy Measurement and Terrestrial Gamma-ray Flash detection

Hien PHAN[1*], Hien VO[2], Hong Hai VO[3], Philippe LAURENT[4], Yannick GERAUD-HÉRAUD[4]

1. University of Science and Technology of Hanoi (USTH) 2. Vietnamese-German University (VGU)
3.Vietnam National University Ho Chi Minh City - University of Science (VNUHCM-US) 4. APC Laboratory, Paris Diderot University (APC)

Introduction

Terrestrial Gamma-Ray Flashes (TGFs) are bursts of gamma-rays forming during a thunderstorm. Fishman et al. (1994) discovered TGFs using the Burst and Transient Source Experiment (BATSE) detectors onboard the Compton Gamma Ray Observatory (CGRO). The scintillation detectors of the BATSE instrument were sensitive above 20 keV. Since then, these intense flashes of gamma rays have been observed mainly from space (upgoing TGFs, in the contrary to the downward TGFs). The data from space has considered these flashes is produced at the altitude between 10 - 15 km. The origin of TGFs are still under investigation. Some scientists have suggested that the TGFs originated as Bremsstrahlung radiation from the Relativistic Runaway Electron Avalanches (RREA) (Dwyer et al., 2008, 2012; Gurevich et al., 1992). The Monte-Carlo simulations have also been established in order to get better study of TGFs, using the models of photons that are transported in the atmosphere. Østgaard et al. (2008) has developed a Monte-Carlo model, and the behavior of TGFs has been modeled by Berge and Celestin (2019). A simulated typical spectrum of TGF as seen from the ground, is shown in Fig. 1 and Fig. 2.

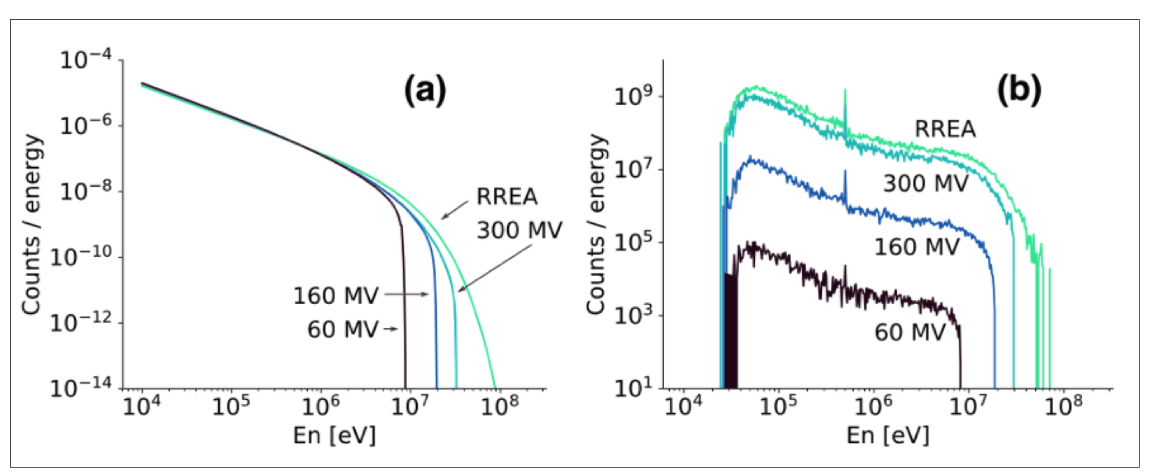

Figure 1:(a) a RREA spectrum with cutoff at 7.3 MeV (green line), and (b) the TGF has been simulated as the photo energy spectra as seen from ground (Berge and Celestin, 2019).

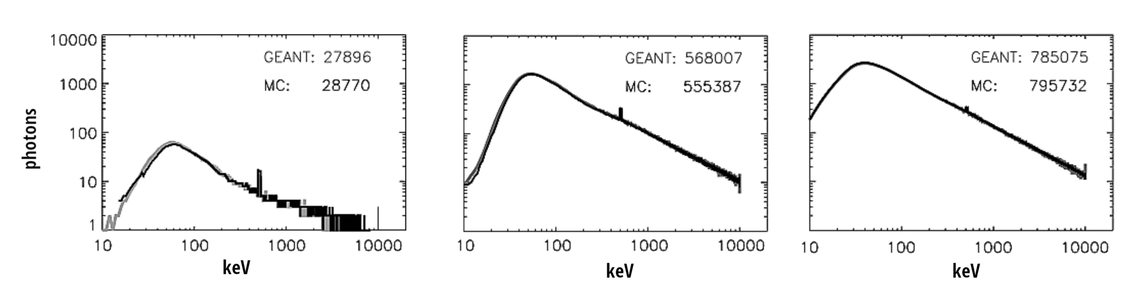

Figure 2:Simulated TGFs by GEANT-4 at different altitudes (15 km, 30 km, 45 km) by Østgaard et al. (2008). The most clear peak is at 15 km (top figure).

The goal of this research proposal is to discover and monitor the downward TGFs by developing a platform and payload of the detector system that can be used as a TGF observatory. The payload will include an IGOSat prototype detector (Phan et al., 2018), using a CeBr3 crystal scintillator (in-organic) and five EJ-200 plastic scintillators (organic) (see Fig. 3), readout by Silicon PhotoMultipliers (SiPMs) and analyzed by a suitable electronics board.

IGOSat prototype detector

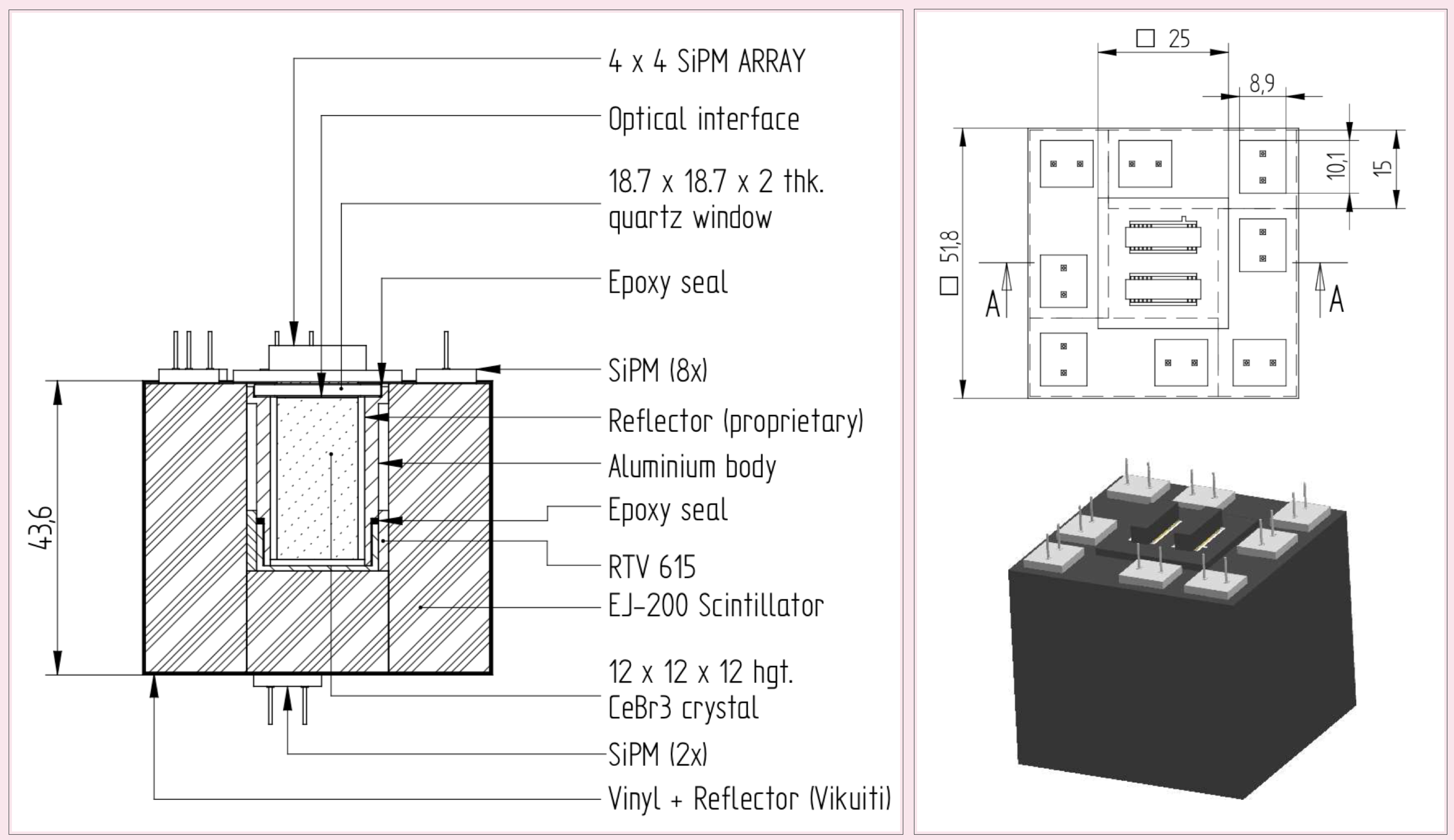

Figure 3:Latest design of IGOSat detector.

Technical solutions

The detector is composed of two kinds of scintillator: in-organic scintillator (Cerium Bromide crystal – CeBr3) and plastic scintillator (organic). The idea of the detector is a crystal scintillator surrounded by plastic scintillators, following the design of the IGOSat nanosatellite that is developed in Paris Diderot University. This design is useful for discriminating between two types of particles since the gamma photon can interact only in plastic scintillator and the electron can interact in both materials. It is also useful for detecting particles coming from any direction (see Fig. 4).

When a particle passes through or is absorbed in the material, it loses energy and excites the electrons in molecules and then produces scintillation photons in the visible range: the higher the energy of the incoming particle, the more scintillation photons produced. From this physical relationship, the energy of particles can be determined by counting the amount of produced scintillation photons. The scintillation photons are then detected by the SiPMs and convert into current under a high voltage. The signal is then processed by an ASIC or by an appropriate circuit.

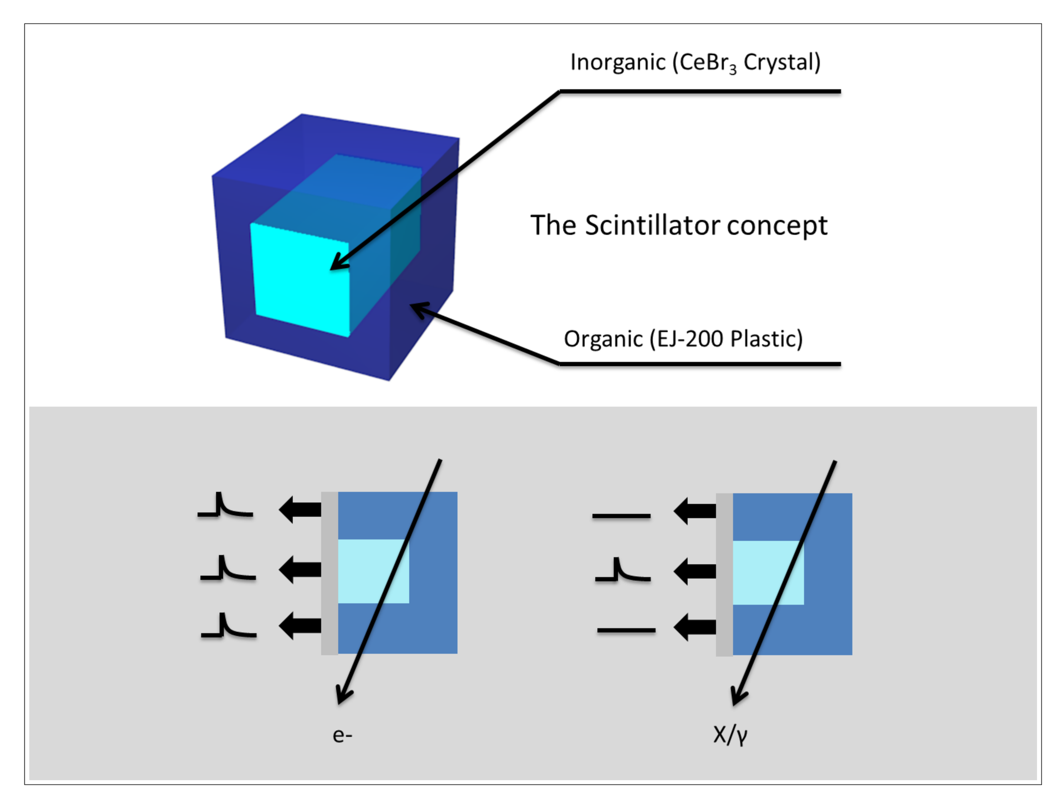

Figure 4:Concept of the IGOSat detector. Since the CeBr3 can detect both gamma-rays and electrons, it is required to cover it with plastic scintillators that detect charged particles only in order to discriminate the two types of particles

Experimetal Methodology

Ground observatory

The system can be set up as a ground observatory on a high mountain or high building. In this case, it can be used to test the possibility of TGF detections. An interesting location is Doi Inthanon in Thailand, which is a mountain with a peak at 2565 m, where the Princess Sirindhorn Neutron Monitor (PSNM) is located. The thunderstorm season in this area is in May, and the PSNM can see enhanced count rates during thunderstorms. So it is reasonable to put the detector at the top of this mountain for testing.

The IGOSat detector can provide valuable additional data in gamma-rays and charged particles for comparison. We also expect the detection ability of gamma-rays from cosmic ray showers at Doi Inthanon, which also could lead to publications in peer-reviewed journals.

This observatory can be set up at Tay Nguyen University, where a thunder lightning distance monitoring system has already been installed.

Balloon flight

Another approaching method can be considered, or to be developed/prepared for the next projects, is to launch this system onboard a balloon or a sounding rocket. For example, a weather balloon can fly from ground to an altitude of about 30 km. The location can be in Vietnam or Thailand. During these flights, the system is able to measure the gamma-ray and electron backgrounds continuously from ground to cruise altitude. Once launched, the scintillator payload will measure the spectra of gamma rays and electrons from ground to an altitude of about 30 km. The measurement can be restricted to the vertical probing of the atmosphere at given locations (short duration flights) or all along the path of longer duration balloon flights.

Acknowledgements

This project will be the first collaboration of the University of Science and Technology of Hanoi (USTH) - which has advantages in space science and satellite technology; the Vietnamese-German University (VGU) - which has advantages in mechanical, mechatronics, electronics and electrical engineering; the Vietnam National University Ho Chi Minh City - University of Science (VNUHCM-US) - which has advantages in particle physics; and the strong support from AstroParticle and Cosmology Laboratory (APC, Paris Diderot University, France).

Contact Information

- Dr. Hien PHAN, University of Science and Technology of Hanoi (USTH)
- Email: phan-thanh.hien@usth.edu.vn